

# Hybrid Power Filter to Enhance Power Quality in a Medium-Voltage Distribution Network

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**Abstract**—This paper deals with the problem of reactive power and harmonics in a standard medium-voltage (MV) distribution network. It proposes a simple and inexpensive solution to enhance power quality when a particular connection to the high-voltage transmission network is required. It presents the design of a hybrid active filter topology connected to the MV level of a power distribution system. Its main task is to regulate a 132-kV voltage level. Reconfiguration of the power delivery network imposes new constraints in a distribution substation so that the reactive compensation should be increased. The topology of a shunt hybrid active filter is analyzed. It is built with the series connection of a passive filter and a low-rated active filter. The proposed filter is directly connected to a 13.8-kV level with no need of a step-down transformer. The possibility of different levels of reactive power compensation is implemented. The proposal shows very good performance for different load demands.

**Index Terms**—Active filters, harmonic distortion, power distribution, power quality, reactive power.

## I. INTRODUCTION

THE NONLINEAR loads and equipment in the consumer side and the renewable energy sources in the generation side give birth to new problems in electrical systems. Then, power electronics appears as an essential interface to improve power quality [1], [2]. Voltage distortion, due to current harmonics, has become a major problem for the utilities at distribution levels. Utilities frequently encounter harmonic-related problems such as harmonic interactions between utility and loads, reduced safe-operating margins, reactive power, resonance problems, higher transformers and line losses, and derating of distribution equipment [1], [3].

The use of traditional compensation with capacitor banks and passive filters produces harmonic propagation, i.e., harmonic voltage amplification due to the resonance between line inductances and shunt capacitors. Therefore, different active solutions have been continuously analyzed in recent years [4]–[6]. A lot of research on different topologies has been done

to improve power quality [5]. The correct placement of the active filters in a distribution system has been investigated [7]. A lot of care is taken on different control strategies to obtain the desired objectives [8]–[13].

The feasibility of using an active solution to solve a particular problem of an actual power distribution grid is considered in this paper. Reconfiguration of the network imposes new constraints on different distribution substations (DSs). Harmonic studies were performed considering the future configuration of the network. Voltage distortions in different points of the network, together with the working conditions of the capacitor banks, were verified by means of harmonic flow [14]. A preliminary proposal suggested increasing the existing passive compensation with capacitor banks from 3 to 6 Mvar, but this solution introduced resonances near the fifth and seventh harmonics, resulting in unacceptable distortion levels. A second proposal (analyzed in [15]) considered a pure shunt active power filter. This, being an excellent solution when the load can be modeled as harmonic current sources, is not so effective when the load presents certain impedances as usual. Therefore, a hybrid solution is proposed here to solve the particular problem of enhancing the 132-kV level in a radial connection of the medium-voltage (MV) network.

Among all the compensation alternatives, the hybrid topologies appear very attractive in the distribution networks where some passive compensation is already installed. In particular, the hybrid shunt active filter formed with the connection of a low-rate active filter in series with one or several passive filters is gaining attention [4], [16]–[19]. Such a combination between active and passive filters allows significantly reducing the rating of the active filter. Its main tasks are to improve the filtering performance and to avoid the resonance problems introduced by passive filters. Moreover, no extra components are required to filter the ripple caused by the power inverter. It constitutes a simple and cheap solution for harmonics in a power distribution network.

This paper is organized as follows. The network configuration and the harmonic problems are described in Section II. The shunt hybrid active power filter (SHAPF) is analyzed in Section III. Section IV presents the design of the hybrid filter. Its performance is evaluated in Section V. Finally, conclusions are drawn in Section VI.

## II. NETWORK DESCRIPTION

The 132-kV network, where the DSs under study are connected, is a meshed network connected to the 500-kV high-voltage transmission system through two points. In the

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